EVALUATION OF GEOLOGICAL RELATIONSHIPS TO GAS HYDRATES FORMATION AND STABILITY:

SUMMARY REPORT

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EXECUTIVE SUMMARY

Geoexplorers International, Inc. has conducted research on the geological factors which control the presence of offshore gas hydrates at 21 locations worldwide. We have applied the methods of regional basin analysis to assess gas hydrates in a variety of sedimentary and tectonic settings. The research indicates that both sedimentary and structural processes control the occurrence of gas hydrates in the sediments of continental margins. The principal economic potential of gas hydrates is as an unconventional source of natural gas. More near-term potential applications include traps and pathfinders for conventional hydrocarbons and indicators of subsurface geologic conditions.

Natural gas hydrates are solid compounds composed of water and hydrocarbon gases. Gas hydrates are stable at high pressures and low temperatures when sufficient quantities of hydrocarbons are present. The pressure and temperature conditions needed for gas hydrates exist in sediments beneath permafrost. Gas hydrates also exist in some marine sediments where the hydro- static pressure exerted by the overlying water column is sufficient for hydrate formation. The necessary pressure generally restricts gas hydrates to sediments beneath water of at least 300 to 600 m depth. Higher sediment temperatures at greater subbottom depths destabilize gas hydrates; therefore, hydrates are found only in the upper 300 m to 1,000 m of marine sediments. Adequate temperature and pressure conditions for gas hydrate formation occur in shallow sediments of continental slopes and rises and abyssal plains of all the world's oceans.

The principal component of offshore hydrates is methane. Methane concentrations in pore water must exceed the prevailing solubility limit for hydrates to form. Methane solubility generally increases with depth within the gas hydrate stability zone, from 50 mM/L at the seafloor to 140 mM/L at 500 m subbottom for marine sediments beneath 1,000 m of water. Methane in gas hydrates is dominantly formed by microbial processes. Thermogenic gas has contributed to gas hydrate occurrences in continental margins sediments of the Pacific, Gulf of Mexico, and Caribbean regions where thermally mature sediments, migrational pathways, and hydrate formation conditions exist. Gas from sub-thrust sedimentary sources and abiogenic methanogenesis may have formed gas hydrates at certain sites along Pacific continental margins.

Sedimentary processes which promote efficient methane generation and migration enhance gas hydrate formation in continental margin sediments. An adequate supply of organic matter to the sea floor and effective preservation of the organic matter in the sediment column enhances biogenic methane generation in the gas hydrate stability zone. Composition of the inorganic components of the sediment also influence hydrate formation. While organic-rich sediments capable of generating methane abound in the

Middle America Trench, gas hydrate are restricted to permeable zones, including coarse sands and volcanic ash layers. Active margins with lower primary productivity of organic matter and slower sedimentation (e.g. Aleutian Trench) have correspondingly less gas hydrate formation. Gas hydrates occur in passive margin settings such as the Gulf of Mexico and the Arctic Ocean which are characterized by rapid deposition of terrestrial organic matter in deltaic sequences and turbidites.

Fracturing and faulting due to seismic activity, sediment dewatering, and mass wasting provide hydrocarbon migration routes and open space for gas hydrate formation. Sediment dewatering, particularly in conjunction with shale diapirs, produces fractures and transports methane in solution to the gas hydrate stability zone. The massive gas hydrate sample recovered from the Guatemala continental margin formed in a fault zone in during active hydrocarbon migration. Imbricate thrust-fault systems in accretionary prisms along convergent margins actively deliver methane to the gas hydrate stability zone.

The amount of methane contained in offshore gas hydrates may range up to 50,000 trillion cubic feet (tcf). Estimated potential gas resources in interstitial gas hydrates for each region studied range up to 1,000 tcf. However exploitation of these potential resources is not yet economically viable. Smaller, but less dispersed massive gas hydrates deposits in fault zones may be the first offshore gas hydrate resource to become economic. Applicability of existing exploration methodology enhances the economics of massive hydrate deposits, especially when they are located offshore of countries without conventional hydrocarbon resources.

Conventional natural gas or oil trapped beneath the gas hydrate zone may be a more economical target than the natural gas contained in the hydrates. We have mapped individual structural traps beneath gas hydrate seals in the Gulf of Mexico, Caribbean, and Arctic regions with sufficient closure to contain potential gas resources of up to 70 tcf.
The presence of gas hydrates provides useful information for exploration for conventional oil and gas deposits. Gas hydrates indicate ongoing hydrocarbon generation in the sediments. Hydrates are valuable to assess the present heat flow and thermal history of a region. Since gas hydrates exist only under a very limited range of pressure and temperature, deviation in patterns of hydrate occurrence can be related to changes in pore water chemistry, hydrocarbon composition, or to anomalies in pressure and temperature gradients.